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Investigating Teachers' Perceptions of STEM Education in Private Elementary Schools in Abu Dhabi

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Abstract

One of the furthermost essential reforms in education is STEM (Science, Technology, Engineering, and Math) education. To implement STEM education effectively at the elementary level, the teachers must be well equipped to face the complicated web that enshrouds the STEM education field. Identifying teachers' perceptions of STEM education is considered one of the ultimate significant processes that need to be considered by the STEM education stakeholders as the teachers' STEM practices are highly influenced by their perceptions of STEM.

The purpose of this study was to investigate the teachers' perceptions of STEM education in Abu Dhabi private elementary schools. The researcher conducted an empirical study with a mixed methods design to meet the purpose of the study. 75 STEM elementary teachers from different private schools in Abu Dhabi participated in this study via an online survey method. The instrument of this study was a teacher questionnaire which was adopted from the valid and reliable cross-sectional Vietnamese survey of Thi To Khuyen et al. (2020) based on their official permission.

The quantitative findings related to the teacher questionnaire revealed that 75% of the elementary teachers in STEM private schools in Abu Dhabi strongly understand what STEM education is and they strongly agreed that STEM competencies are extremely important. Yet, 50% of the teachers agreed that they find difficulties in implementing STEM education. Qualitative data related to the teacher questionnaire revealed that these difficulties were related specifically to the lack of STEM resources, the constraint of time, and the need for professional development.

This study is unique in the UAE as no studies up to the best of the researcher's knowledge were conducted to investigate the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. Hereafter, this study is significant by contributing to the STEM literature in the UAE. More, the results of the study are valuable in terms of stipulating implications for STEM elementary education program developers as teachers' perceptions affect and shape their decisions in STEM field.

Keywords: STEM education, STEM perception, elementary level, Abu Dhabi, STEM private schools

1. Introduction

Science, Technology, Engineering, and Mathematics subjects are referred to in education by the acronym STEM (Hacioglu & Gulhan, 2021; Permanasari et al., 2021). STEM has no definitive definition (Dare et al., 2019; Gao et al., 2020). In fact, in some places, it substitutes the terms of mathematics and science (Breiner et al., 2012); however, in other places, it denotes a farther integrated approach to teaching and learning that imposes explicit affiliations among disciplinary content and practices (Delahunty et al., 2021; Kelley & Knowles, 2016; Permanasari et al., 2021), where students are expected to "work in the context of complex phenomena or situations on tasks that require them to use knowledge and skills from multiple disciplines" (Honey et al., 2014, p. 52).

The literature related to integrated STEM approaches reveals common features. These features are: the inclusion of an engaging real-world context (Dare et al., 2019; Delahunty et al., 2021; Permanasari et al., 2021), the premeditated and explicit liaisons between the four domains: science, mathematics, engineering, and technology (Gao et al., 2020; Honey et al., 2014; Sirajudin & Suratno, 2021), the modeling of the four domains as they will potentially be utilised in STEM careers (Kelley & Knowles, 2016), the intended insertion of the 21st-century skills such as collaboration, communication, creativity, and critical thinking (Bryan et al., 2015; El Sayary et al., 2015; Hacioglu & Gulhan, 2021; Honey et al., 2014), the use of technology to create and communicate innovative solutions (Sirajudin & Suratno, 2021), and lastly an accent on the student-centered academic strategy to support apprentices developing problem-solving and critical thinking skills (Bryan et al., 2015; Hacioglu & Gulhan, 2021; Permanasari, Rubini, & Nugroho, 2021; Rinke et al., 2016; Sirajudin & Suratno, 2021).

To be implemented in an effective way, the STEM's four disciplines have to be addressed via the principles of Vygosky's social development theory (Vygotsky, 1978). For instance, in STEM classes, students should socially interact and actively collaborate to solve real-world problems, develop their critical thinking, and build their own learning experience. Moreover, STEM education has to be approached through a learner-centered approach where students have to be at the center of the learning process by actively participating and contributing to all hands-on STEM activities held in class, as per the Dewey's theory of integration principles (Dewey, 1938; Hassan et al., 2019). Although STEM education requires the students to be the main and active participants in class, yet, STEM teachers play a vital role in the students' learning process. They are the mentors who facilitate the students' learning process by providing a suitable learning environment in order to scaffold their cognitive skills, and attain their learning goals (Hassan et al., 2019; Vygotsky, 1978).

STEM education originated in the United States (US) as SMET (Science, Mathematics, Engineering, and Technology) at the beginning of the 1990s (Martín-Páez et al., 2019) with the National Science Foundation (Kelley & Knowles, 2016) where the US Government created a learning program to prepare the high school alumni to be capable to compete internationally (Breiner et al., 2012). In the last decade, numerous researches have appraised the movement of STEM education especially in the secondary school level (Hudson et al., 2015) such as, in Australia (English, 2016; Timms et al., 2018), in India (Bhagat & Vijayaraghavan, 2019), Finland (Su et al., 2017), the United Kingdom (Smith & White, 2019), Africa (Barakabitze et al., 2019), Asia (Lee, Chai, & Hong, 2019; Shahali et al., 2016), Spain (Castellanos, Haya, & Urquiza-Fuentes, 2016; Toma & Greca, 2018), the United States (Beckett et al., 2016; Suter & Camilli, 2019; Toth, 2016), and in the middle east such as in Saudi Arabia (Madani, 2017), Lebanon (Makarem, 2019), and Jordan (Al-Haj Bedar & Al-Shboul, 2020; Al-Muhaisin & Khaja, 2015).

STEM education is considered new in the UAE (Al Murshidi, 2019). In fact, it was implemented in the UAE in 2010 when several schools adopted the Next Generation Science Standards (NGSS) in their science curricula (Ahmed, 2016). Many initiatives were taken by the STEM promoters in the UAE to implement effective STEM education as the UAE economy is moving from being oil-based to knowledge-based and that requires more students to graduate as scientists and engineers (National Academies of Sciences, 2018). Sheikh Mohammed bin Zayed, Crown Prince of Abu Dhabi stated that the UAE students' practises of engineering, technology, and finance are imperative to the information-economic revolution in UAE and he encouraged them to join scientific fields and careers.

The purpose of this study was to investigate the teachers' perceptions of STEM education in Abu Dhabi private elementary schools. Identifying teachers' perceptions of STEM education is considered one of the ultimate significant processes that need to be considered by the STEM education stakeholders and researchers (Srikoom et al., 2017) since first, teachers are considered the cornerstone for the advancement of education and its sustainability, and second, their perceptions of STEM education affect their practices in classrooms (Thi To Khuyen et al., 2020). A teacher questionnaire was administered to elementary STEM subject teachers (Science, Mathematics, ICT) in the mentioned schools in order to investigate their perceptions of STEM education and to answer the following main question: What are the elementary teachers' perceptions of STEM education in private schools in Abu Dhabi?

This study is unique in the UAE as no studies up to the best of the researcher's knowledge were conducted to investigate the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. Hereafter, this study is significant by contributing to the STEM literature in the UAE. More, the results of the study are valuable in terms of stipulating implications for STEM elementary education program developers as teachers' perceptions affect and shape their decisions in STEM field. Additionally, this study will be a basis and a reference for further research in elementary STEM education by tackling the dearth of quantitative analysis and by adding to the present pool of qualitative knowledge vis-à-vis the elementary STEM education in the United Arab Emirates (UAE).

2. Conceptual Framework

To meet the purpose of this study, which is to investigate the teachers' perceptions of STEM education in Abu Dhabi private elementary schools, it was beneficial to construct a conceptual framework (Figure 1) that encompasses a network of related components that influence the main concept of the study which is the STEM education (Kelley & Knowles, 2016). Studies disclose that STEM education is affected by a series of systematic associations linking different concepts that can be categorized under two categories: interpersonal and structural (Al Quraan & Forawi, 2019). The interpersonal category includes the teacher's knowledge and willingness, the value teachers place on STEM, the relevant, authentic, and meaningful experience for participants alongside the teacher collaboration, and the outside support, such as support from advisors and scientists.

For instance, the teacher's knowledge of STEM education is described as all the accommodated information about the characteristics of STEM education, its benefits and drawbacks as well as the integration of its different disciplines (Sujarwanto & Ibrahim, 2019). The knowledge required for effective STEM education is broad and multifaceted. In fact, content knowledge, pedagogical knowledge, technological knowledge, student knowledge, assessment knowledge, and curriculum knowledge are the essential components of teacher knowledge (Chan et al., 2019).

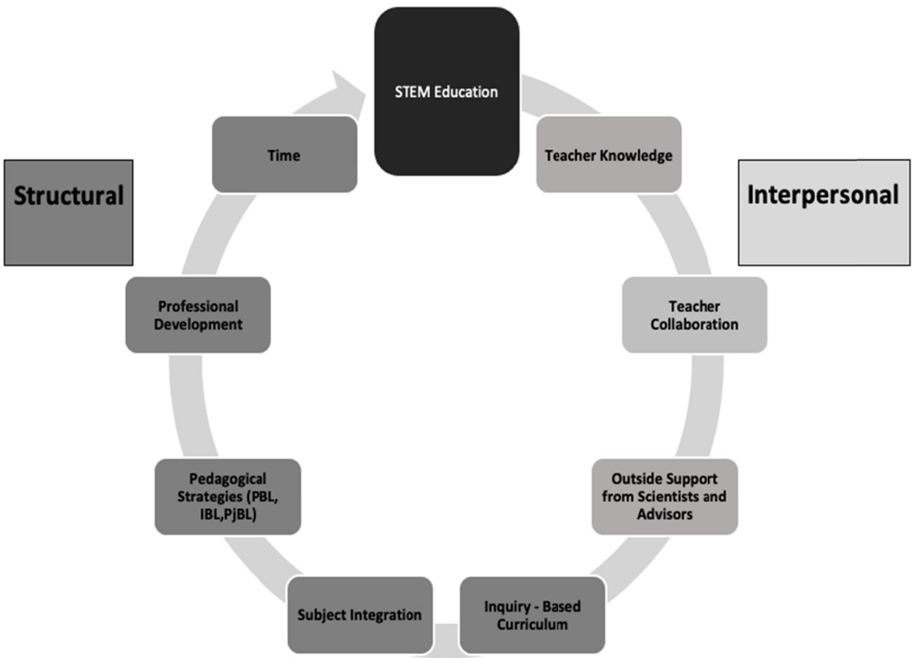

Figure 1. The conceptual framework of the present study

Collaborating with other STEM teachers enhances the sustainability of STEM programs and creates an effective learning atmosphere where the teachers' preparation for STEM lessons are improved (Herro & Quigley, 2017; Margot & Kettler, 2019). Also, the earlier teaching experience using pedagogical methods such as Problem-Based Learning (PBL) or Inquiry-Based Learning (IBL) as well as student-centered methods seems to increase the confidence of teachers in practicing STEM education (Park et al., 2016).

Thus, the structural category is related more to physical things that should be in place for an effective STEM implementation such as STEM curriculum, STEM content, subject integration, Problem-Based Learning (PBL), PjBL (Project-Based Learning), Design-Based Learning (DBL), time, professional development opportunities, and outside support, such as support from organisations, museums, science centers, and industries. Yet, for effective STEM integration, the latter factors should be present and should interact within an effective STEM learning environment. For instance, the presence of a quality, coherent, rigorous, inquiry-based, well-defined, flexible, and experiential integrated 21st-century STEM curriculum design founded on STEM concepts, tightly driven by standards, and compelled with clear goals and objectives would improve the probability of realization of STEM initiatives and implementation (Lehman, Kim, & Harris, 2014). Moreover, STEM curriculum should be present with its STEM pedagogical content emphasizing the four STEM disciplines (S-T-E-M) and the different integrated subjects that should target real-world issues by adopting different pedagogical strategies with their various integrating methods such as PBL, PjBL, and DBL and their assorted cognitive integration areas such as planning, applying, experiencing, and discovering.

The STEM pedagogical content is related to the teacher's content knowledge and willingness to implement STEM which is affected by the teacher's authentic experience afforded by the school leadership and management. The school district support is mentioned as a vital factor for STEM success (McMullin & Reeve, 2014) and the teacher administrative support and guidance by constant communication along with teacher flexibility to expand the instruction beyond the national standards are mandatory for a successful STEM implementation (Bruce-Davis et al., 2014; El-Deghaidy, 2017). The teacher's content knowledge along with the professional development (PD) opportunities which are considered the main implementation factors for integrated STEM. For instance, research demonstrates that the availability of frequent and well-organised professional learning opportunities influences positively the teachers' practices and eases the success of STEM implementation (Lesseig et al., 2016).

Eventually, constant training and workshops are also needed for teachers' collaboration which is considered a must in a STEM community or a 21st-century learning environment. Teachers should acquire, adapt, and sharpen the questioning skills and the tactics for effective classroom management where they are expected to call on a range of strategies for illumining STEM topics, planning scientific experiments, directing students in scientific inquiry, and making sense of data (Ejiwale, 2012). Also, time is needed for Professional Development, planning, collaboration, reflection, teaching, implementation, and authentic STEM assessment. Time availability is considered a crucial factor for a successful STEM implementation besides the availability of funding, advisory services, outside support, and resources such as high-quality materials and technology tools which are considered the main factors for an effective STEM implementation.

Lastly, studies reveal that the support of and the partnership with science community-based-centers are beneficial for teachers as they help them feel more comfortable in taking risks and in delving deeper into STEM concepts outside their comfort area (Al Quraan & Forawi, 2019; El-Deghaidy, 2017; Honey et al., 2014; Margot & Kettler, 2019; McLoughlin et al., 2020; Pugalenthi, 2019; Walker et al., 2018).

3. Literature Review

3.1 STEM Teacher Perceptions

Teachers play a significant role in implementing STEM education successfully (Wang et al., 2011). Yet, the teachers' STEM practices are highly influenced by their perceptions of STEM (Thibaut et al., 2018). Existing studies and related literature (2010–2020) reveal insights into the teachers' perceptions of STEM education. In their study, Margot and Kettler (2019) claim that teachers' perceptions of STEM education are dependent on teachers' demographics and they argue that the teacher's age, gender, and education background are factors that affect the teacher's perception of STEM education as the teacher's positive attitude towards STEM increases when the teacher's age increases. In general, male teachers have a more positive view of STEM education than female teachers and the number of related STEM courses taken in college eases the teachers' job and prepares them to teach STEM. Hence, this claim contradicts Srikoom, Hanuscin and Faikhamta's (2017) findings which state that teachers' backgrounds do not influence the teachers' perceptions of STEM education, but support Park et al.'s (2016) claims which suggest that teachers' preparation to teach STEM seems to be a valuable factor that affects STEM education and its implementation.

Regarding the teachers' years of experience factor, Thibaut et al. (2018) assert that novice teachers express a less positive view of STEM education compared to experienced teachers. Contrarily, Srikoom, Hanuscin and Faikhamta (2017) declare that the teachers' years of experience seem to be inconsistently related to teachers' perceptions of STEM education, and the teacher's interest in STEM education may intervene in this inconsistent relationship. Parker, Kruchten and Moshfeghian (2017) added that when the teachers' years of experience increase, the teachers' readiness to STEM implementation increases, but only if they value STEM education, and if not, the increasing number of years of experience does not affect the teachers' feelings of readiness to teach STEM. Margot and Kettler (2019) affirmed that the value the teachers place on STEM education does not only affect the feeling of readiness to teach STEM, yet it also influences the teachers' willingness to implement STEM curriculum. Bell (2016) added that the teachers' perceptions of the importance of STEM education affect their ability to learn and develop STEM and therefore the way to teach STEM. Additionally, Holstein and Keene (2013) stated that teachers' beliefs in student abilities affect their perceptions of STEM education.

The teaching subject seems to play a critical role in teachers' perceptions of STEM education. For instance, studies reveal that science teachers have a more positive view and a better willingness to implement integrated STEM education compared to mathematics teachers who feel that it is challenging to help students in solving authentic problems (Wang et al., 2011). Moreover, teachers of different grade levels have different perceptions of STEM education. A study conducted by Al Basha (2018) in the UAE revealed that the middle school and the secondary school teachers unveiled higher optimistic perceptions and better implementation of STEM education compared to the elementary school teachers. They also showed better collaboration and more understanding of STEM content and pedagogical approaches.

Furthermore, teachers with different educational levels develop altered knowledge levels and different personal perceptions of STEM education. For instance, teachers with master's and doctoral degrees reveal a better understanding and a more positive view of STEM education (Thi To Khuyen et al., 2020). Similarly, teachers with different backgrounds or majors might have dissimilar perceptions of STEM education (Thibaut et al., 2018). The reason for this dissimilarity, as per the researchers, goes back to the way the teachers had been taught and guided during their education (Jarski et al., 1990). Alternatively stated, the way each teacher perceives and teaches STEM is dependent on her/his own experience when he/she was a student (Bandura, 1977). For instance, Al Basha's (2018) findings revealed that teachers' majors have significant impacts on STEM implementation and problem-solving practices and teachers with science and technology backgrounds exhibited positive and better practices of problem-solving than teachers with mathematics backgrounds.

Furthermore, teachers believe that STEM education is required to promote the students' 21st-century skills such as collaboration, creativity and research, reasoning, problem-solving, and technological and inquiry skills. Thus, despite the in-service teachers' positive beliefs and views towards STEM education, teachers ask for in-service professional development learning opportunities such as workshops to deal with the challenging implementation of interactive STEM curricula, to improve their skills and abilities in planning STEM group-oriented activities, to be able to evaluate educational approaches suitable for each STEM activity, and to authentically assess STEM students (Altan & Ercan, 2016). For instance, research studies reveal that group-oriented activities within an interactive curriculum increase the teachers' enjoyment of teaching science and enhance the students' scientific achievement (Wang et al., 2011). For that reason, the delivered professional development (PD) sessions have to be coherent, active, reflective, collaborative, and sustained. Moreover, they need to focus on the teacher content and technology knowledge. The PD needs to emphasize the pedagogy of enactment such as how to apply different student-centered learning approaches along with problem-solving techniques as major components to integrate STEM disciplines. Lastly, PD needs to emphasize how to implement PBL, PjBL, and IBL strategies, for authentic knowledge construction and real changes to occur in practice (Estapa & Tank, 2017; Jordan et al., 2017; Margot & Kettler, 2019; Mitts, 2016; Moore et al., 2014; Wang et al., 2011).

Being not well-prepared to teach STEM education efficiently during the pre-service period, the in-service STEM teachers have to deal with STEM curricula and their challenging implementations in STEM schools, leading to unsuccessful STEM teaching and learning. Therefore, STEM scholars need to take into consideration the preparation of the pre-service STEM teachers that need to be effective future STEM teachers and stakeholders (Chalmers et al., 2017). Cooper and Gilbert (2016) stated that pre-service teachers (PST) always express a desire to deliver and teach STEM in more successful and engaging methods than they were taught. Thus, their future pedagogical practices of STEM education depend not only on their desire to implement STEM effectively but on their perception of STEM education.

The PSTs' perception of STEM education is affected by STEM conceptualization. The teachers' conceptualization of STEM forms a mental framework that implicitly guides their teaching and practices of integrated STEM and prioritizes concepts over each other during their future careers as STEM teachers. Studies reveal that in most cases, PSTs conceptualise STEM as an integrative approach that utilizes PBL and IBL by emphasizing the connections between the four STEM disciplines to develop the students' skills and prepare them for future careers (Chalmers et al., 2017).

Furthermore, several psychological factors affect the teachers' perception of the PSTs of STEM education. For instance, teachers' attitude to teaching STEM influences the teachers' perceptions and practices of STEM education. Attitude is defined as an influential construct or a salient predictor that affects the direction and the intensity of future behavior (Ajzen, 2005). Commonly, PSTs reveal a positive attitude to teaching STEM education. Yet, they claim an uncertainty in developing their professional capacities at a time when they are exposed to limited engaging opportunities to enhance their STEM teaching (Blackley & Howell, 2019; Chalmers et al., 2017). Additionally, a higher self-efficacy in teaching STEM is related to good teaching practices, specifically student-centered pedagogies. Self-efficacy portrays the individual's perception of how skillful, knowledgeable, and able he/she is to perform a determined behavior (Kraft et al., 2005). Moreover, it is the belief of how successful an individual is in achieving an important task (Estrada et al., 2016). Hinojosa et al. (2016) confirmed that self-efficacy is a significant predictor of the STEM PSTs success. However, Chalmers et al. (2017) claimed that PSTs expressed low levels of self-efficacy in teaching STEM education disciplines, especially engineering and technology.

Accordingly, STEM stakeholders need to modify and develop the current approaches in teaching STEM education by assisting the PSTs in identifying the different STEM models and pedagogical approaches of integrated STEM, by providing them with authentic opportunities and engaging them in STEM activities to develop their teaching capacities and improve their attitude towards STEM, and by increasing their self-efficacy in STEM teaching, especially in engineering and technology to improve their perception of STEM education and to prepare them for fruitful future STEM careers (Blackley & Howell, 2019; Chalmers et al., 2017).

4. Methods

In this study, the population is described as a pool of individuals with similar characteristics where the researcher can draw the sample of the study from (Mertens, 2010). Grade one to Grade five elementary science, mathematics, and technology (ICT) teachers or STEM teachers who teach in private elementary schools in Abu Dhabi which adopt and implement the STEM curriculum are the target population. Convenience sampling, which is a non-random sampling method that considers collecting data from target individuals who conveniently are accessible and ready to participate in a study, was used to access the target population in the study (Creswell & Clark, 2017). Seventy-five STEM elementary teachers from different private schools in Abu Dhabi participated in this study via an online survey method. The instrument of this study was a teacher questionnaire which was adopted from the valid and reliable cross-sectional Vietnamese survey of Thi To Khuyen et al. (2020) based on their official permission. In fact, although there is plenty of research with surveys that examine the teachers' perceptions of STEM education (Al Salami et al., 2017; Park et al., 2016; Thibaut et al., 2018; Wang et al., 2011), these studies focused on investigating the teachers' perceptions mainly via a variety of components, such as conception, attitudes, beliefs, difficulties, or self-efficacy (Thi To Khuyen et al., 2020). However, STEM education is framed into three aspects: STEM education, STEM competencies, and STEM difficulties (Berlin & White, 2012; Bybee, 2013; Diana & Sukma, 2021; El-Deghaidy et al., 2017; Lee & Shin, 2014; Margot & Kettler, 2019; Saptarani et al., 2019; Thi To Khuyen et al., 2020; Wang et al., 2011). Therefore, the researcher chose and adopted the cross-sectional Vietnamese survey of Thi To Khuyen et al. (2020) as it measures teachers' perceptions of STEM education following three components: (1) STEM education, (2) values of STEM competencies, and (3) STEM difficulties. It consisted of twenty-one quantitative questions, scored on a five-point Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree). Three questions related to the teachers' overall perceptions of STEM education such as "Teachers can combine optionally science, technology, engineering, and mathematics knowledge in the current curriculum to compose STEM lessons" and "Scientific inquiry and Engineering design are two main factors in a STEM lesson". Seven questions were related to the teachers' value of STEM competencies such as "STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians" and "STEM education can help students leverage collaboration literacy with others to execute STEM learning projects". Eleven questions were related to the teachers' difficulties in STEM implementation such as "Difficulty to implement an inquiry-based curriculum" and "Difficulty to authentically assess students' achievement (formative and summative assessments)".

Despite the advantages of the utilization of the Likert scale questionnaire as a means to gather quantitative data, it is a bit challenging to capture the teachers' perceptions of a wide topic as STEM education via a limited number of multiple choices questions. Furthermore, participants might understand the different questions differently from what the researcher intended (Madani, 2017). Therefore, an additional qualitative section was added to the questionnaire by the researcher to minimize its limitations and maximize its benefits (Madani, 2017). The last section of the questionnaire consisted of a set of five structured, open-ended qualitative questions, which required the teachers to reflect on their perceptions of STEM education by typing their answers using their own words in a comment box. Bryman (2016) posited that with open-ended questions, participants are asked questions and are free to reply "however they wish" (p. 244). The five questions that helped the researcher to qualitatively interpret and analyze the perceptions of STEM elementary teachers, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM effectively were the following: 1) How do you define STEM education? 2) What challenges do you face when you implement STEM education in your classroom? 3) Do you collaborate with other teachers to discuss STEM lessons? And how often? 4) Did you receive professional development to support you in STEM education in your school? and how often? 5) How often did your students participate in STEM competitions? and what types of competitions do your students participate in? Moreover, by using the participants' own words, the open-ended questions helped the researcher reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. The open-ended questions were utilized to validate the quantitative data and to attain a wider comprehensive understanding of the STEM teachers' perceptions in private elementary STEM schools in Abu Dhabi (Creswell & Clark, 2017). To ensure their clarity and validity, the researcher asked STEM key informants to review the open-ended questions which were developed by the researcher in the qualitative part of the teacher questionnaire. The questions of the teacher survey were transferred by the researcher to the SurveyMonkey tool and an online link to the online teacher questionnaire was generated to access it.

5. Ethical Considerations

The present research encompassed minimal risk. It entailed disseminating an online teacher survey for a number of teachers enrolled in STEM private elementary schools in Abu Dhabi. In that sense, the researcher did not expose the teachers to any possible hurtful or illegal behavior, nor the opposite was probable. Also, the researcher had no connections or aforementioned history with the target schools which reduce the chances of any conflicts of interest (Yin, 2015). More, all the participants were informed via an introductive letter, on the top of the teacher survey, about the purpose, the benefits, and the risks of the present study as well as their roles in the study. The agreement of participating in the teacher survey was required from the participants in the first question of the survey after assuring them that the survey was totally anonymous and that their participation was entirely voluntary and deciding not to participate or to withdraw from participating at any time would not result in any harmful consequences and there were no identified physical, psychological, or social risks allied with the present study. The collected data was confidential. The researcher was the only one who had access to it to code it, analyze it, interpret it, and to draw conclusions.

6. Results

6.1 Teachers' Perceptions of STEM Education: Quantitative Findings

Descriptive statistics were utilized to summarize and organize the quantitative data set related to the teachers' perceptions of STEM education in STEM schools in Abu Dhabi and to address the question of the current study. The statistical package for social sciences (SPSS) version 22.0 was utilized to describe and analyze the teachers' perceptions of STEM education after creating a codebook to code the collected data. Measures of central tendency were calculated through mean scores and standard deviations (Table 1) to examine and interpret the overall teachers' perceptions among the three STEM domains which are the general understanding of STEM education ($M = 1.67$, $SD = 0.616$), the values of STEM competencies ($M = 1.36$, $SD = 0.381$), and the difficulties in STEM implementation ($M = 2.36$, $SD = 0.703$). More, Figure 2 elucidates the boxplots which illustrate the distribution of the three STEM domains. The general observation revealed that the box plots of the first and the second domain were comparatively short while the box plot of the third domain was comparatively tall. This means that overall teachers had a high level of agreement of the definition and the values of STEM competencies. Whereas, they held quite different opinions regarding the STEM difficulties.

Table 1. Descriptive statistics of STEM domains

	MEAN	STD.DEVIATION	STD.ERROR
STEM UNDERSTANDING	1.671	.616	.071
STEM VALUE OF COMPETENCIES	1.360	.381	.440
STEM DIFFICULTY	2.364	.703	.081

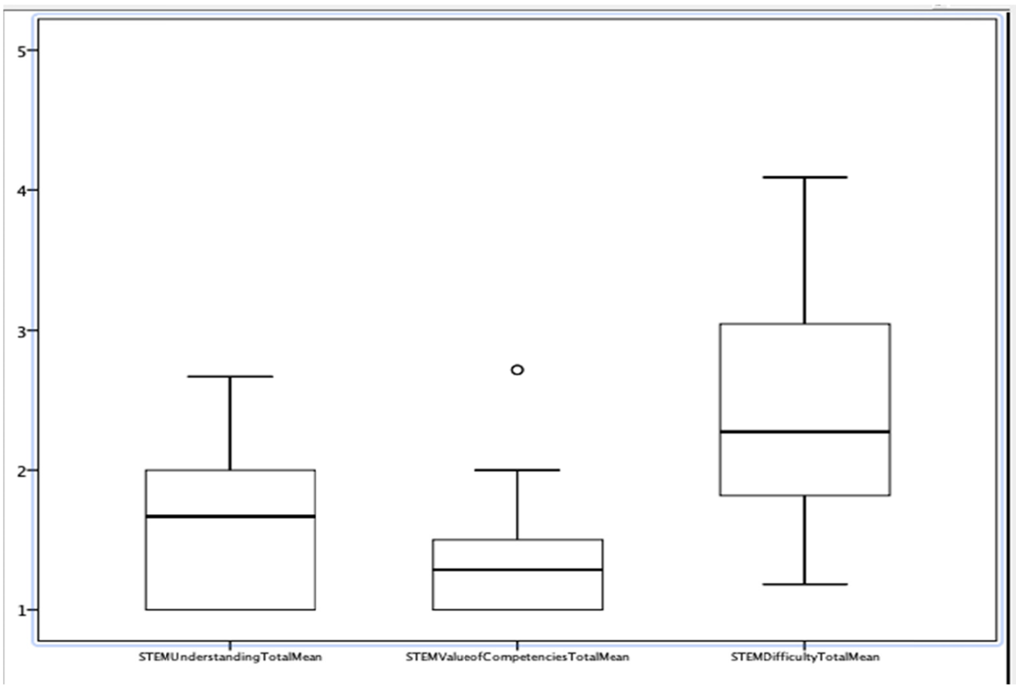

Figure 2. Distribution of STEM domains: STEM general understanding; Value of STEM competencies; Difficulty in STEM implementation

To answer the teacher questionnaire, teachers were asked to assess the value of each STEM competency and level of STEM implementation difficulty based on five-point Likert scale of agreement to disagreement quantitative questions (1) Strongly agree, (2) agree, (3) neither agree or disagree, (4) disagree, (5) strongly disagree. Findings revealed that "STEM can help students acquire engineering abilities to make meaningful products" was perceived as the most important STEM competency (M = 1.21, SD = 0. 412) while "STEM can help students acquire skills related directly to STEM careers" (M = 1.64, SD = 0.782) was perceived as the least important STEM competency by the elementary teachers in STEM schools in Abu Dhabi. Regarding STEM difficulties, the two items: to manage STEM activities (M = 2.73, SD = 1.085) and to implement an inquiry-based curriculum (M = 2.69, SD = 0.929) were perceived as the most tolerated difficulties in implementing STEM education. Whereas, the need for Professional Development (M = 1.93, SD = 0.949) and the insufficient time for students to conduct STEM lessons (M = 1.94, SD = 0.984) were perceived as the main difficulties in comparison with all the other difficulties when implementing STEM education (Tables 2 and 3).

Table 2. Measures of central tendency of each item of STEM competencies

	MEAN	STD.DEVIATION
D-STEM education can help students acquire skills related directly to STEM careers.	1.640	.782
E-STEM education can help students develop scientific literacy.	1.306	.614
F-STEM education can help students develop technological skills.	1.333	.528
G-STEM education can help students acquire critical thinking that is usually conducted by scientists, technologists, engineers, and mathematicians.	1.346	.532
H-STEM education can help students acquire authentic problem-solving skills to make a decision in the real world.	1.306	.614
I-STEM education can help students to better collaborate with each others to execute STEM learning projects.	1.373	.486
J-STEM education can help students acquire engineering abilities to make meaningful products (define the needs, design, and make a certain product).	1.213	.412

Table 3. Measures of central tendency of each item of STEM difficulties

	MEAN	STD.DEVIATION
K-Need to enhance knowledge beyond your major, related to STEM subfields (Technological, pedagogical, and content knowledge)	2.320	.960
L-Difficulty to implement an inquiry-based curriculum	2.693	.929
M-Difficulty to authentically assess students' achievement (formative and summative assessments)	2.653	.937
N-Difficulty to plan STEM activities	2.693	1.196
0-Difficulty to manage STEM activities	2.720	1.085
P-Difficulty to evaluate the suitable approach for each STEM activity.	2.466	.949
Q-Insufficient time for students to conduct STEM lessons	1.946	.984
R-Need an extra support from school administration, scientists, and advisors.	2.066	1.082
S-Need to collaborate more with other STEM teachers	2.226	1.021
T-Need for Professional Development	1.933	.949
U-Difficulty in preparing students for national and international STEM competitions (Robotics, Coding, Innovation competition)	2.293	.881

6.2 Teachers' Perceptions of STEM Education: Qualitative Findings

This section presents the elementary teachers' responses gathered from a set of five structured, open-ended qualitative questions included at the end of the distributed questionnaire. The five open-ended questions allowed the researcher to investigate the perceptions of STEM elementary teachers by qualitatively analyzing their understanding of STEM education, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM in an effective way. Hence, the researcher aimed to investigate the frequency of STEM teachers' meetings to collaborate and discuss STEM activities. Furthermore, the last question highlighted the students' preparation and participation in STEM competition in the UAE to highlight STEM ways of celebration and to evaluate the extent of the importance delegated to STEM on a national level in STEM schools in Abu Dhabi. The teachers were required to respond and to reflect on their perceptions of STEM education by typing their answers using their own words in a comment box. The section of the five open-ended questions included the following:

1) How do you define STEM education?

2) What challenges do you face when you implement STEM education in your classroom?

3) Do you collaborate with other teachers to discuss STEM lessons? And, how often?

4) Did you receive professional development to support you in STEM education in your school? And, how often?

5) How often did your students participate in STEM competitions? And, what types of competitions do your students participate in?

The qualitative analysis of the open-ended questions was achieved by utilizing Krathwohl (2009) three main stages to help the researcher attaining a wider comprehensive understanding of the STEM teachers' perceptions and to reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. Moreover, the analysis of the qualitative data was utilized to corroborate the findings of the quantitative data. The Krathwohl's (2009) three main stages consisted of (1) familiarization and organization of the participants' answers, (2) coding and recoding of the findings, and (3) summarization and interpretation of the findings. Qualitative findings related to teachers' perceptions of STEM education revealed that ninety percent of the teachers in STEM schools in Abu Dhabi were able to give clear definitions of STEM education. Eighty percent agreed that they were facing challenges when implementing STEM activities in their classes, specifically regarding the lack of resources, the constraint of time, and the need of professional development. Concerning the teachers' collaboration, around eighty-five percent of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities. Vis-à-vis school support, seventy percent of the teachers claimed that they often receive support from their schools (training, workshop) but they asked for specific professional development in STEM to enhance their knowledge in STEM education, implementation, and design. Concerning the students' participation in STEM competition, ninety percent of teachers agreed that their schools rarely participated or did not participate in STEM competition at a school level or national level.

6.3 Discussion of the Quantitative Results Related to Teachers' Perceptions of STEM Education

The objective of this study was to identify the teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. The researcher collected data from seventy-five STEM elementary teachers via a survey method from different private schools in Abu Dhabi. The teachers were asked to answer twenty-one questions scored on a five-point Likert scale. The questions addressed queries related to three clusters: (i) teachers' overall perceptions of STEM education, (ii) teachers' value of STEM competencies, and (iii) teachers' difficulties in STEM implementation.

The quantitative analysis of the collected data revealed that the majority of elementary teachers have positive views of STEM education; they have a good understanding of STEM education and they strongly agree on the values of STEM competencies. Nevertheless, half of the teachers claimed that they find difficulties in implementing STEM education.

The teachers revealed a general understanding of STEM education and they perceived STEM education as a teaching method where they can combine optionally knowledge from science, technology, engineering, and math disciplines to compose a STEM lesson. Moreover, they agreed that scientific inquiry and engineering design are two main factors in a STEM lesson. These findings support further the results obtained by Al Basha (2018) in the UAE. The teachers who participated in Al Basha's study showed an informed understanding of the STEM definition. Additionally, they revealed that engineering is the best practice of STEM education, and similarly, these findings are in agreement with that of Thi To Khuyen et al. (2020) and Margot and Kettler (2019). Participant teachers had reasonable general understanding of STEM definition and believed that the cross-curricular connections made in STEM education and learning provide the students with the necessary skills to solve real-world problems, especially via engineering inclusion. A study conducted by Smith, Rayfield and McKim (2015) revealed that teachers believe that engineering adds real-world and practical aspects to teaching and learning and prepares students for their future by helping them solve real-world problems.

These findings are in line with the NGSS framework (2013) which articulated and discussed the role of engineering in science education and included engineering concepts as part of the science academic standards, as well as in accordance with the UAE Ministry of Education's 2017–2021 strategic plan which aims at preparing students for the knowledge-economy and the needs of the job-market by equipping them with creativity and critical thinking skills via strategies and values that endorse knowledge integration in engineering, science, and innovation.

"STEM can help students acquire skills related directly to STEM careers" was perceived as the least important STEM competency by the elementary teachers in STEM schools in Abu Dhabi. These findings ally with those of Thi To Khuyen et al. (2020). Yet, Takeuchi et al. (2020) posited that around forty percent of the studies related to STEM education focus on students' interests to pursue STEM-related careers. Hacioglu and Gulhan (2021) confirmed that STEM education affects indirectly the students' career awareness. Hayden et al. (2011) asserted that STEM education increases elementary students' motivation, attitude, and interest towards science and encourages them to pursue STEM careers in the future.

To help teachers implement STEM in an effective way and to positively impact the students' careers ambitions, the STEM stakeholders have to enhance the teachers' pedagogical teachings as they directly affect the students' careers objectives. Therefore, Professional Developments need to be delivered to engage teachers not only to understand STEM education, but also to enhance their awareness of STEM careers (Thi To Khuyen et al., 2020).

Teachers in elementary schools in Abu Dhabi reported that they face challenges in implementing STEM education, especially in implementing an inquiry-based curriculum. This reflects challenges in teachers' STEM pedagogical knowledge and content knowledge. These findings mirror those of Tairab (2010) who indicated that teachers in the UAE face many challenges regarding STEM pedagogical content knowledge, especially the lack of content knowledge in science in elementary education (Forawi, 2020). They also match those of Thi To Khuyen et al. (2020) where teachers struggled with the content knowledge and pedagogy knowledge when implementing STEM. Moreover, they broadly support the results obtained by Shidiq and Nasrudin (2021), where elementary teachers struggled in integrating the STEM subjects and in offering contextual aspects relevant to the elementary students' real-life.

These findings are likely to be the results of the teachers' tendency to implement conventional teaching by teaching separate subjects in separate lessons oriented to their own disciplines (El-Deghaidy & Mansour, 2015), or they are likely related to the teachers' struggles to teach disciplines they do not master (lack in content knowledge) and to difficulties in teaching and implementing integration (lack in pedagogy knowledge) (Thi To Khuyen et al., 2020). To overcome these challenges, it is recommended to enhance the teachers' content knowledge of STEM disciplines beyond their majors. Moreover, teachers are asked to shift their pedagogical habits to implementing the cross-cutting concepts and meeting the core idea of STEM learning (Chesnutt et al., 2019).

The teacher's ability to use proper technology, effective interdisciplinary content knowledge of STEM disciplines, and pedagogical knowledge needed to deliver the STEM challenging standards to transfer the correct knowledge for learners and to face the STEM students' learning difficulties and misconceptions in a technology-based learning environment can be seen via the TPACK framework (Mishra & Koehler, 2006; Yulisman et al., 2019).

Parker et al. (2015) stated that STEM association with technological, pedagogical, content knowledge (TPACK) is fundamental in developing the students' twenty-first-century skills as STEM education requires teachers to integrate technology, pedagogy, and associated content knowledge through design. TPACK also facilitates the teachers' job and the authentic students' learning via design thinking.

Therefore, professional trainings on STEM based contextual learning are mandatory to be delivered to elementary STEM teachers to enhance their technological, pedagogical and content knowledge in STEM. The aim of professional trainings is to overcome the challenges in implementing STEM education, to become STEM thinkers, to sustain STEM education, and to prepare scholars for the technological revolution that the world is experiencing (Shidiq & Nasrudin, 2021; Thi To Khuyen et al., 2020).

6.4 Discussion of the Qualitative Results Related to Teachers' Perceptions of STEM Education

This section discusses the teachers' answers on a set of five structured open-ended qualitative questions. The questions at the end of the teacher questionnaire required the teachers to explain further and reflect on their perceptions of elementary STEM education. The five questions that helped the researcher interpret qualitatively and analyze the perceptions of STEM elementary teachers, the difficulties they face when implementing STEM education, and the extent of support they receive to implement STEM in an effective way, were the following: 1) How do you define STEM education? 2) What challenges do you face when you implement STEM education in your classroom? 3) Do you collaborate with other teachers to discuss STEM lessons? And how often? 4) Did you receive professional development to support you in STEM education in your school? and how often? 5) How often did your students participate in STEM competitions? and what are types of competitions your students participate in?

The open-ended questions helped the researcher reveal any possible overlooked aspects related to STEM education in private elementary schools in Abu Dhabi. The qualitative questions were developed by the researcher based on the insights of the documents' analysis, in the first qualitative phase of the study, in addition to the insights gathered from the conceptual framework and the literature review of the present study. The open-ended questions were utilized to validate the quantitative data and to attain a wider comprehensive understanding of the STEM teachers' perceptions in private elementary STEM schools in Abu Dhabi.

1) *How do you define STEM education?*

In the first question, few teachers defined STEM as per its acronym where they denoted "*STEM Education, at its core, simply means educating students in four specific disciplines, namely, Science, Technology, Engineering, and Mathematics*". Navy et al. (2021) emphasized the significance of developing teachers' understanding of STEM beyond its acronym for science, technology, engineering, and math, especially at the elementary level. In addition, the researchers highlighted the necessity of enhancing the teacher's STEM knowledge and skills at the elementary level to better prepare the students for the future.

Nonetheless, the majority of the participants were able to give clear and detailed definitions of STEM education. This finding corroborates the quantitative findings in the teacher questionnaire which revealed that the majority of the elementary teachers in STEM schools in Abu Dhabi have a general understanding of STEM education. For instance, teachers posited that STEM education is "*An innovative teaching method that integrates knowledge from different disciplines to enhance students' problem-solving skills; A multidisciplinary approach to tackle current challenges and solve real-life problems via hands-on activities; A key to innovation; A set of inter-related disciplines that develop students' critical thinking and help students gain the skills required to succeed in today's challenging world; Education that involves scientific inquiry and engineering practices; 21st century skills need; It is generally implemented via PBL*."

These findings differ from those of Alumbaugh (2015) who stated that elementary STEM teachers do not have clear understanding of STEM education. Yet, they highly match those of Madani (2017) and Thi To Khuyen et al. (2020). The STEM various definitions in this study support those of Koonce et al. (2011) who stated that

STEM education definition is ramified but called for a unified STEM definition that best encounters the educational needs of students and suits their country needs. Additionally, the attained results including definitions that call for integrative teaching approaches via hands-on activities, PBL, and engineering practices to solve real-world problems reflect the STEM teaching practices' requirements revealed in the related literature (Dare et al., 2014; Van Haneghan et al., 2015; Williams et al., 2015) and advocated by early childhood teachers (Park et al., 2016). Hence, they mirror the Drake's (1991) theory of integration which advocates for a transdisciplinary approach that associates STEM with real-world applications to empower students with twenty-first-century skills so as to encounter future careers problems (Smith et al., 2015).

Nevertheless, teachers did not focus on the students' collaboration when they defined STEM education, despite the fact that this twenty-first-century skill is considered a significant factor in STEM education implementation, especially at elementary level as it helps students to interact socially and find innovative solutions related to their real-life problems (Le et al., 2018; Rosita & Leonard, 2015). Indeed, the collaborative hands-on STEM activities support the learning by doing and enable the students to exhibit higher levels of knowledge (Dewey, 1938; Vygotsky, 1978). Neither did the teachers focus on STEM ability in preparing the students for future careers despite the fact that they valued this competence the most in the quantitative part of the questionnaire.

2) *What challenges do you face when you implement STEM education in your classroom?*

In the second question, the elementary teachers shared similar perceptions related to the challenges and difficulties in implementing STEM such as "*the shortage in resources, the shortage in innovative ideas for STEM activities, the constraint of time, the lack of administrative support, the need of training, the lack of pedagogical knowledge, the need for more collaboration between colleagues, the lack of quality and flexible curriculum, and the lack quality assessment tools*".

These findings support those of Henriksen (2017) and Margot and Kettler (2019) who described the teachers' challenges in practicing STEM education. Moreover, they highly reflect those of Shidiq and Nasrudin (2021) who depicted the teachers' obstructions in implementing STEM at the elementary level. Additionally, the teachers' answers revealed additional reasons behind the quantitative results of the teacher questionnaire which highlighted that half of the teachers face challenges in implementing STEM education, especially in implementing an inquiry-based curriculum in private elementary schools in Abu Dhabi. For instance, the need for more PD and the constraint of time to implement STEM activities were the most repetitive obstructions revealed by the elementary teachers.

"*The need for more PD to enhance the pedagogical knowledge, to acquire innovative ideas for STEM activities, to authentically assess STEM projects, and to implement integrated STEM curricula*" was revealed by elementary teachers in this study and was consistent with Kelley and Knowles (2016), Nadelson et al. (2012), Madani (2017), Fisher, Frey and Pumpian (2012), and Forawi (2020) descriptions of STEM challenges and need for PDs implementation to provide the maximum impact on elementary teachers' practices of STEM education.

Whereas the "*constraint of time*" to implement effective STEM highly reflects the findings of Park et al. (2016) and Bagiati and Evangelou (2015) who posited that the workload associated with STEM practices within the school's busy schedules requires extensive time and hinders effective STEM implementation. It also mirrors the findings of Abdallah (2017) who claimed that one the main barriers that challenged her teachers to design and implement STEM projects in the UAE schools was the time constraint.

Teachers also declared that they need to "*collaborate more*" to better implement integrated STEM. This finding mirrors McFadden and Roehrig (2017) argument on the necessity of teachers' collaboration in planning and designing STEM activities and teachers' collaboration with external companies to better understand STEM education, STEM practices, and real-life problems to prepare their students for future careers (Vennix, den Brok, & Taconis, 2017).

Additionally, "*the lack of quality and flexible curriculum*" mirrors the findings of Van Haneghan et al. (2015), McMullin and Reeve (2014), and Forawi (2020) who posited that STEM teachers call for a quality and flexible STEM curriculum with ready-made STEM problems as they believe that it is imperative for successful STEM initiatives and it helps them acquire higher self-efficacy to teach STEM and to implement it immediately in their classes (Asghar et al., 2012).

Furthermore, the revealed teachers' challenges mirror the findings of Malaka (2018) and Al Basha (2018) in the UAE. Malaka (2018) disclosed that STEM implementation in the UAE necessitates further support for teachers via professional training and workshops; whereas, Al Basha (2018) claimed that teachers in her study complained about a dearth of professional training. They also reported a deficiency of significant collaboration among the diverse parties in school and the inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity.

Furthermore, few elementary teachers in private elementary schools in Abu Dhabi argued that there is a "*shortage in STEM resources*" to implement STEM education. These findings mirror those of Malaka (2018) and Al Basha (2018).

Hence, the teachers' request for "*valid and authentic STEM assessment tools*" is in agreement with that of Nadelson and Seifert (2013) and Herro and Quigley (2017) who claimed that teachers argue that there is a lack of assessments for STEM programs, a difficulty in assessing STEM lessons, a concern of group grading, and an unease in assessing each member of the group. Sabri (2015) asserted that the utilization of formative assessment strategies to assess students' comprehension in science classrooms in the UAE enables teachers to collect evidences regarding students' understanding. This helps them amend their teaching strategies in order to tackle the students' scientific misconceptions and build their critical thinking skills.

3) *Do you collaborate with other teachers to discuss STEM lessons? And how often?*

In this question, the majority of teachers claimed that they often meet and collaborate with other teachers to plan and reflect on STEM activities. These findings highly support those of Malaka (2018) in the UAE, where teachers affirmed that they collaborate to plan STEM activities. They also mirror the findings of Goodnough, Pelech and Mary (2014) where elementary teachers collaborate to plan, share, and reflect in order to conceptualize and implement their STEM action research projects. Asghar et al. (2012) posited that teachers' collaboration is significant in STEM planning and implementation. Margot and Kettler (2019) argued that teachers' collaborative planning is critical to STEM successful implementation. Also, Alumbaugh (2015) stated that collaboration among STEM elementary teachers is very beneficial.

However, few teachers claimed that they do not collaborate to design STEM activities and they asked for more collaborative opportunities to design STEM activities and implement STEM efficiently. These findings mirror those of Al Basha (2018) where teachers reported a deficiency of significant collaboration among the diverse parties in school and the inadequate time to implement STEM activities which all result in implementing STEM as an activity per term or as an extra-curricular activity. Hence, this reflects the teachers' request for more collaborative STEM sessions in question two to overcome STEM challenges and better implement integrated STEM.

4) *Did you receive professional development to support you in STEM education in your school? and how often?*

The elementary teachers' answers came different to this question. Most of the teachers claimed that they often receive support (training, workshop) from their schools. Yet, they asked for specific STEM related PDs to enhance their knowledge and practices in STEM education.

The revealed findings validate the teachers' quantitative answers when they asked for more PDs to overcome their STEM challenges. Forawi (2020) claimed that elementary teachers in the UAE face many challenges such as the lack of content knowledge in science.

These findings are consistent with those of Goodnough, Pelech and Mary (2014) where elementary teachers asked for PD to increase their competences in STEM education. They also mirror those of Goodnough, Pelech and Mary (2014) where elementary teachers required PDs that provide effective collaborative, relative, and contextual opportunities to meet their needs in STEM education.

Guskey and Yoon (2009) stated that in STEM, the context is as important as the content. Han, Capraro and Capraro (2015) claimed that PDs enhance the teachers' STEM skills and practices and empower them to deliver successful STEM education. PDs also support the teachers, motivate them, and clarify their misunderstanding of STEM content and core concepts (Hammack & Ivey, 2019) especially if they are delivered over a lengthy period of time (Fisher et al., 2012).

However, few teachers asserted that they receive little support or no support at all from their school related to STEM education, e.g., "*once in a year or none related to STEM design*". These findings are in agreement with those of Malaka (2018) where most of participants claimed that they do not receive PDs related to STEM education. Additionally, they highly support those of Shaer, Zakzak and Shibl (2019) who claimed that teachers in the UAE have a lack of structured training in STEM education which obstructs their deliverables.

Parker (2011) asserted that professional development supports teachers in STEM teaching and learning, especially if it focuses on teachers' content knowledge, pedagogical needs, curriculum needs, and collaboration and if it is linked to students' learning. Forawi (2020) added that delivering professional development for teachers to explore STEM as an integrative approach to learning by focusing on student-centered and problem-solving techniques in order to meet the twenty-first-century skills requirements and to recognize its importance in motivating students in teaching and learning is considered a significant factor for an effective STEM implementation.

5) *How often did your students participate in STEM competitions? and what are types of competitions your students participate in?*

In this question, few teachers asserted that their students participate in coding and robotics competitions between schools or on a national level. These claims reflect those of Forawi (2020) who stated that students' interests in science and STEM related areas are sparkled in their participation in school projects or via rare STEM programs in the UAE such as the Advanced Technology Investment Company (Mubadala Investment Company, 2013).

This finding aligns with the UAE Government's National Agenda that aims to foster students' innovation, creativity, and ambition by encouraging them to put their STEM knowledge to the test and to compete on a national level to find practical solutions to real-world challenges. These practices empower the students' minds and help developing future leaders become capable to contribute to the UAE economy and to embrace the evolving technological world we live in (Abu Dhabi University, 2021; Fouad, 2018).

However, most of the teachers agreed that their schools rarely do or do not participate at all in STEM competitions at a school level or at national level. Barcelona (2014) and Munn et al. (2018) asserted that participating in STEM competitions and celebrating STEM students' wins spark the students' motivation, enjoyment, and interest in STEM areas. Also, it allows them to be highly engaged in scientific discussions and experiments. Moreover, STEM competitions and celebration help the STEM scholars to identify what works and needs to be improved in STEM education. Furthermore, Forawi (2020) stated that STEM competitions enhance the students' interdisciplinary research skills and outline their career choices.

7. Implications for Practices

Based on the study results, the following are key recommendations that can be beneficial to promote the teachers' perceptions of STEM education and to facilitate its implementation at the elementary level.

Schools are recommended to offer STEM elementary teachers Professional Development sessions. These sessions have to be ongoing, contextualized, and customized to align with the elementary teachers' instructional needs and the students' learning needs. Moreover, they have to model STEM practices implemented at the elementary level to help teachers translate STEM theories and curricula into practices. They also have to support teachers in their STEM content, pedagogical, technological, and management knowledge to be able to handle STEM classrooms, interdisciplinary approaches and strategies, and technological tools. Moreover, PD sessions have to involve STEM careers instructions to help the teachers bridge the gap between STEM in manpower and STEM in education.

In parallel, schools have to give special attention to the availability of STEM resources and to the time for teachers to collaborate, plan, and discuss STEM activities as teachers complained from lack of resources, the constraint of time, and the need to collaborate with other subjects' teachers or like-minded peers who understand and value STEM to facilitate STEM integration. Once the teachers' issues are addressed, their perceptions of STEM education positively increase, and therefore, the students' motivation in STEM areas increases.

The STEM elementary teachers find challenges in finding methods to assess the integrated STEM projects which are of non-traditional nature in private schools in Abu Dhabi. This is due to the absence of a unified framework of STEM application, the lack of quality assessment for STEM implementation, and the severe deficiency in valid and reliable instruments to assess the students' comprehension of STEM content and the outcomes of STEM intervention and classroom practices. Related literature suggested that students' learning has to be assessed via formative assessments as they suit the nature of the STEM learning process. Therefore, STEM stakeholders are recommended to deliver workshops related to formative assessments that focus on students' learning process for teachers to apply them effectively and continuously. Hence, these workshops should aim at promoting their abilities in developing formative assessment tasks and rubrics to evaluate the students' deliverables towards the STEM educational goals and to increase their understanding of STEM education.

The majority of the teachers in this study had a general understanding of STEM education. Yet, few were still unable to define it correctly. Related literature asserted that STEM elementary teachers have to be knowledgeable in STEM education and well informed about the advantages of STEM education at primary level to engage, inspire, and nurture the students' interests in STEM areas. Therefore, schools are recommended to hire teachers with qualifications related to STEM disciplines and STEM pedagogy to ensure they are equipped with content and pedagogical knowledge necessary for effective STEM integration and practices. If not, periodic Professional Developments are a precondition for teachers to enhance their STEM content and pedagogical knowledge.

8. Recommendations for Future Researchers

Future researchers are highly recommended to consider including interviews to gain better qualitative insights from the participants on their perceptions of STEM education and the difficulties they face in implementing it. As well as, classroom observation of STEM elementary classes is recommended to present an extensive description of the STEM practices in the mentioned schools and to validate the findings of this study. Moreover, investigating teachers' perceptions of STEM education in STEM inclusive schools in Abu Dhabi at the middle and high school levels is recommended to complement this study. Lastly, a comparative study between this study and a replicated study in STEM inclusive elementary governmental schools is significant to unveil differences and similarities between the practices, integrated curricula, and STEM stakeholders' perceptions in private and governmental elementary schools.

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